Evaluation of Flood Proofing Options For Residential Property in Massachusetts

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This study has been conducted under the Corps of Engineers Section 206 Floodplain Management Services Program. The purpose of this investigation is to provide to flood-prone property owners the various alternatives to reduce or eliminate future flooding losses.

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EVALUATION OF FLOOD PROOFING OPTIONS FOR RESIDENTIAL PROPERTY IN MASSACHUSETTS

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May 1997

EVALUATION OF FLOOD PROOFING OPTIONS FOR MASSACHUSETTS HOMEOWNERS

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PREFACE

The New England District of the U.S. Army Corps of Engineers (COE) conducted this evaluation of flood proofing options for residential property in Massachusetts at the request of the Massachusetts Department of Environmental Management (MDEM). The work was conducted under the Corps Flood Plain Management Services (FPMS) program. The FPMS program is authorized under Section 206 of the Flood Control Act of 1960 (PL 86-645).

This study provides information to flood-prone property owners about the steps that can be taken to reduce or eliminate future flooding losses and also draws upon information obtained from Massachusetts communities that have successfully implemented flood hazard mitigation improvement projects.

CHAPTER 1: INTRODUCTION

Prior to the 1960's, the management of floodplains was often described by the term "flood control" and was usually characterized by the construction of large flood control projects and smaller local protection projects. Billions of dollars were spent nationwide on dams, reservoirs, and levee systems to control the country's flood waters, and these structures have been instrumental in reducing or eliminating economic losses during subsequent flood periods. Since the 1960's the use of management techniques which "modified the susceptibility to flood damages" rather than "modifying the flooding or the floodplain" became popular approaches to addressing flood damages. This includes ***flood proofing***. Flood proofing is defined as "any combination of structural or non-structural changes or adjustments incorporated in the design, construction, or alteration of individual buildings or properties that will reduce flood damages."[1] Simply stated, flood proofing includes any efforts property owners may take to reduce flood damages to buildings or their contents. This document compares general cost guidelines with actual flood proofing project costs, including projects completed in Massachusetts.

WHY FLOOD PROOF ?

Flood proofing residential property can be an extremely cost effective way of reducing or eliminating flood related damages and expensive clean-up costs. Flood proofing can be as simple as moving vulnerable contents above flood elevations prior to the onset of flooding or as complex as elevating the entire structure above the 100-year flood elevation. Flood proofing also has the secondary benefit of reducing flood losses while maintaining the beneficial uses of floodplains. This reduces the potential to exacerbate flooding problems downstream and does not promote increased development in the natural floodplains which can occur with structural projects. Flood proofing projects can be accomplished either by

[1] National Flood Proofing Committee

individual property owners or as part of larger publicly funded projects. If no actions are taken to resolve these problems, home owners will continue to experience property and content damages and communities will continue to incur expensive response and recovery costs. By implementing some form of flood proofing, preferably to the level of the 100-year flood level, a certain amount of damage can be avoided.

TYPES OF FLOOD DAMAGE REDUCTION MEASURES

Typically, there are two types of solutions that can be formulated to reduce flood damages; ***structural and nonstructural. Structural*** solutions are those measures that include dams, channels, dikes, walls, and diversion channels. The intent of these solutions is to reduce the frequency and/or the amount of damaging flood flows. ***Nonstructural*** solutions can include flood proofing, permanent relocation of structures, flood warning systems, and the regulation of floodplain lands. The intent of nonstructural solutions is to reduce flood losses without changing the nature or extent of the flooding. This can be accomplished through either reducing the number of times the building is flooded or limiting the potential damage to a building and/or its contents when it is flooded.

Flood proofing measures include elevating buildings, relocating or protecting damageable property within a building, sealing walls, protecting utilities, and incorporating temporary closures within a building. For purposes of this study, low floodwalls and levees around individual buildings and relocation or elevating of structures will also be referred to as flood proofing measures.

Two terms that will be referred to later are "dry" and "wet" flood proofing. ***Dry flood proofing*** refers to the sealing of building walls with waterproofing compounds, impermeable sheeting, and using shields to cover and protect openings from floodwater. ***Wet flood proofing*** involves allowing the structure to be flooded but ensuring, either through permanently or temporarily relocating contents and utilities, that damage is minimized.

CHAPTER 2: FLOOD PROOFING ALTERNATIVES

This section briefly describes various flood proofing alternatives and lists factors that impact the overall cost of the various alternatives. There are three general approaches to flood proofing. These include (1) ***Relocate or elevate the structure***, (2) ***Construct barriers to keep water from entering the structure***, and (3) ***Modify the structure to include relocating utilities and contents to minimize flood damage***. There are three important considerations that homeowners should be aware of as they explore any of the available options.

1. Local regulations should be checked prior to initiating any flood proofing measures. These requirements may limit your options.

2. Some flood proofing may require the use of a professional architect/engineer to design certain measures. Professionals experienced in flood proofing design and construction should always be sought.

3. The aesthetic aspects of any improvement must always be considered. This can affect the marketability of both the improved property and adjacent properties.

In order to select the most suitable flood proofing measure, the property owner must consider the nature of the flood hazard, the physical conditions of the site and the building, and the building's function and structural features. Table 1 provides many key considerations that should be addressed before selecting the appropriate flood proofing measure. The flood proofing alternatives a homeowner may wish to evaluate can be identified by using a flood proofing decision matrix, as shown in Figure 1.

TABLE 1

Key Considerations in Flood Proofing

Flood Characteristics	Site Characteristics	Building and use characteristics
Flood water velocity	Relief/slope	Slab or crawl space?
Depth	Proximity to water	Structural stability?
Rate of flood water rise	Stability of soil	Overall size?
Duration of flooding	Presence of bedrock	Strength?
Debris content	Construction equipment access	Access during flooding?
Historic accounts of previous flooding	Aesthetics	Utility locations?
	Impact upon adjacent properties	Will people be sleeping in area?
	Coastal/riverine	Can area be converted to storage?
	Other hazards (earthquake, wind)	Is area used primarily for storage?
		Type of construction (concrete, brick, etc.)?
		Building condition (excell., good, fair, poor)?
		Historical preservation.
		Accessibility by disabled.

RELOCATION

This method of flood proofing is the most reliable and provides the greatest possible protection from flooding. ***Relocation*** involves moving the building to an alternate location out of the floodplain. However, the structural integrity of the building must be considered as well as the logistical feasibility of such a task. Relocation involves elevating a building onto a wheel-based trailer and taking it to a new location and and lowered onto a new foundation.

Factors that impact the overall cost of relocating a structure include:

(1) Type of Structure
(2) Size, age, & shape of structure
(3) Attached garages
(4) Porches and decks
(5) Utility connections
(6) Land
(7) Moving structure
(8) Foundation construction.

ELEVATION

Elevation of a building is the most widespread application for reducing flood damage problems. Unlike relocation, a new site for the building is not needed and unlike other methods of flood proofing, elevating a structure has the potential to provide almost guaranteed protection from flooding, depending on how high the structure is raised. Elevating structures is adaptable to almost any floodplain environment, coastal or riverine.

Elevation of a structure requires elevating the building in place so that its lowest floor is at or above the level of desired flood protection, usually the 100-year flood level. FEMA recommends that the structure be elevated 1 foot or more above the 100-year flood level for increased protection, and for flood insurance purposes. The building is jacked up and set on a new or extended foundation. The least costly building to raise is the wood-frame structure with a crawl space. As other factors are included, such as a basement, a slab on grade foundation, brick construction, multi stories, or additions, the job becomes more costly. The elevated building can be placed on an extended foundation wall or an open foundation made with piers, columns or piles.

Homeowners residing in ocean front areas have different alternatives to consider when deciding which flood proofing alternative to use. The National Flood Insurance Program (NFIP) regulations and the State Building Code require that structures newly constructed or substantially improved in coastal high hazard areas (V-Zones) be elevated on open pile or column foundations (in addition to other requirements). Additionally, the Building Code requires any structure placed on a new foundation in a V-Zone to meet this standard.

Structures within the coastal floodplain that are not subject to wave attack (coastal A-Zones) may be elevated on solid foundation walls, subject to requirements of other regulations such as the Massachusetts Wetlands Protection Act. This is also true for structures in non-coastal A-Zones.

Extended foundation walls may be used in shallow and low velocity flooding situations. The walls may be extended with reinforced concrete, or concrete block. The connections between the new and existing walls are important. Careful attention should be taken in the structural design of the extended wall as they must be capable of withstanding all associated forces. The NFIP regulations and the State Building Code require that structures newly constructed or substantially improved within A-Zones, be designed to automatically equalize hydrostatic forces acting on the structure. The Building Code requires this standard be met for any structure placed on a new foundation in an A-Zone. This can be accomplished by including hydrostatic openings in the walls, or by designing an open foundation.

Open foundations can be designed in various manners. One method is to place the structure on piers. This is sometimes used in shallow, low velocity flooding situations. Piers sometimes do not withstand lateral flood waters and erosive forces well. Post or columns are also used in the open foundation system. These support units are usually made of wood, steel or pre-cast reinforced concrete. Post or columns are usually anchored into a more solid foundation than piers. Anchoring, along with bracing at the building connection, allows a post or column foundation to resist the forces associated with moderate flood depths and velocities.

The most structurally sound open foundation involves driving steel or reinforced concrete piles deep into the ground. Piles are used in areas of high velocity flood waters as they are very resistant to lateral forces. This is the most expensive open foundation because the driving process usually entails temporarily relocating the building to another location.

Factors that impact the overall cost of elevating a building include:

(1) Type of structure
(2) Size of structure
(3) Shape of structure
(4) Age of structure
(5) Attached garages
(6) Porches and decks
(7) Accessibility (including handicap accessibility)
(8) Stairways
(9) Height of raising
(10) Design difficulty
(11) Extent of mechanical/electrical equipment
(12) Zone A or Zone V special flood hazard areas

LEVEES AND FLOODWALLS

Levees and floodwalls are freestanding structures set apart from the building that is being protected. These flood proofing measures can either completely surround the structure or just protect the low side(s) of the property from flood waters. Levees and floodwalls are advantageous in that they keep flood waters from entering the structure, prevent damage to the structure completely (unless the system is overtopped or fails), and do not require alteration of the structure. Conversely, permitting under local, state, and Federal regulations can be much more difficult to obtain. This is due to the effects these measures can have on flooding and drainage of other properties bordering the site. These structures are usually limited in height to approximately six feet because of space, cost, aesthetic and structural design concerns.

Levees are very effective flood proofing structures constructed of compacted impervious fill. They are designed with side slopes of approximately one vertical to two or three horizontal. As a result, the width is much larger than the height and a large amount of space is needed for construction. The soil under the levee needs to be impermeable to prevent seepage of water into the protected area. If erosive forces are a problem on the exposed portions of the levee, armor stone can be placed to protect it. In most cases, interior drainage improvements must also be included in the overall design of levees. This is to ensure that water from precipitation or seepage is removed from the flood protected portion of the property.

Floodwalls are usually constructed of concrete, stone, or brick, take up far less space, and can enhance the appearance of the building. In general, material for floodwalls are more expensive than for levees. The design of this structure is important in ensuring the wall's stability during a flood. Residential floodwalls are only practical up to a height of six feet.

Some of the critical elements essential to the effectiveness of both levees and floodwalls are closures and maintenance. Openings such as walkways and driveways need to be installed with closures. Closures can be made from various materials but need to be able to withstand the forces exerted by flood waters. These closures can be permanent or inserted just prior to the onset of flood conditions. Inserts must be easily handled for expedient and secure placement. In general, the more openings, the less effective the system. This is due to the increased risk of improper placement or not enough lead time to install the closures. Finally, periodic inspections of levees, walls, and interior sump pumps are needed to ensure the system is properly maintained.

Factors impacting the overall cost of a levee or floodwall include:

(1) Height and size
(2) Availability of suitable foundation and/or fill material
(3) Provisions for interior drainage (e.g., sump pumps, sewer backwater valves)
(4) Number of required closures

DRY FLOOD PROOFING

Dry flood proofing involves sealing building walls with compounds, impermeable sheeting or other materials, and using shields to cover openings. This method of flood proofing is usually done on brick or concrete block structures that are more able to withstand the lateral forces of flooding. Even so, dry flood proofing is not recommended above three feet in height. Also, dry flood proofing should not be used on buildings with crawl spaces or basements as they are susceptible to uplift or buoyancy forces and may be damaged structurally. Waterproofing compounds cannot withstand great water pressure over time. Even with sealing, an intricate system to collect leakage is necessary. Shields can be made of different materials and can be inserted in pre-placed slots when needed, or permanently installed. In general, dry flood proofing is a very complicated procedure that should be designed with the aid of an experienced professional engineer.

Factors impacting the overall cost of dry flood proofing include:

(1) Type of closure material (e.g., wood, steel)
(2) Type and quantity of sealant (e.g., compound, impermeable sheeting)
(3) Provisions for interior drainage (e.g., sump pumps, sewer backwater valves)

WET FLOOD PROOFING

Wet flood proofing involves allowing the water to flood inside the building while at the same time minimizing structure and contents damage. Since floodwaters are allowed to enter the building, uplift and lateral forces are equalized and the potential for structural damage is reduced. Utilities, appliances, or other contents can be protected with a small interior floodwall in cases of shallow flooding in the basement. Otherwise, with deeper flooding they can be raised on platforms or to higher elevations in the building. Some homeowners have permanently relocated utilities to a new utility room above expected flood elevations. Others move contents to higher elevations prior to inundation. Sufficient warning time must be allowed for those who choose to temporarily relocate contents prior to a flood. Flash-flood situations may not lend themselves to this alternative. Those using wet flood proofing should also be aware of hazardous materials and electrical hazards. Wet flood proofing often requires significant clean-up time and cost.

Factors impacting the overall cost of wet flood proofing include:

(1) Utility relocation/elevation
(2) Shielding material for low level flooding
(3) Storage tank anchoring
(4) Plumbing system protection

FLOOD WARNING AND PREPAREDNESS

All ***flood warning and response systems*** have one or both of the following flood related purposes: the prevention of deaths and injuries, and the reduction of property damages. Flood warning and response systems meet these objectives by providing advance warning of floods to community officials and floodplain residents. This enables the removal of cars and building contents from the path of expected floodwaters, the closure of roads and bridges that would be expected to flood, the evacuation of the floodplain, and the performance of other flood mitigation response activities.

There are four critical components of a successfully operating flood warning and response system. These are: (1) flood threat recognition, (2) flood forecasting and warning message creation, (3) warning message dissemination, and (4) flood warning response. These components are summarized below.

1. The flood threat recognition component is the mechanism through which officials are initially made aware of the potential threat of flooding affecting their area.

2. The flood forecasting and warning message component includes both the analysis of data in the preparation of flood forecasts for the covered area and the creation of a warning message to communicate the forecast to the intended audience.

3. The warning message dissemination component is the mechanism of transmitting the warning message to the responsible officials and general public, particularly those in the floodplain. Methods of message dissemination include the use of telephones, police radios, and house-to-house notification.

4. The response component includes all actions taken by the public and private sector to minimize flood related damages.

Although some flood reduction benefit may be achieved without a detailed response plan, maximum benefit from a flood warning system will be obtained only if the response to the flood is carefully planned and integrated within the capabilities and limitations of the flood warning hardware. A flood specific preparedness plan thoroughly addresses the warning message dissemination and response components far in advance of a flood. The preparedness plan should address the procedures to be followed before, during, and after a flood event. The flood specific preparedness plan allows the flood emergency to be "managed", as opposed to a flood emergency being merely reacted to. Preparation of preparedness plans is clearly a local responsibility since it is local authorities that perform local emergency response activities.

Two types of flood warning systems are: 1) systems designed to provide flood warning to persons in a single drainage basin (e.g., local flood warning systems), and 2) systems designed to provide flood warning throughout multiple river basins in a wide geographic area (e.g., statewide flood warning system). Either type of flood warning system is potentially a low cost alternative to structural or regulatory solutions, although neither system type can be expected to completely eliminate all flood damages.

CHAPTER 3: FLOOD PROOFING EVALUATION CRITERIA

There are several site and structure, or physical, characteristics that should be initially considered in determining the type of flood proofing required. This "first step" procedure can be very helpful in assisting a homeowner eliminate certain alternatives and focus on others. These characteristics are listed below.

FLOOD DEPTH

Typically, if flood depths are three feet or less above the lowest floor, some sort of dry flood proofing of the building could be used. If flood waters exceed the three foot level, relocation, elevation, floodwalls, levees, or wet flood proofing may be the method of choice.

FLOOD VELOCITY

Determine if water velocities in excess of three feet per second occur at the site during a flood. Flood water velocities greater than three feet per second will require special consideration on any design.

FLASH FLOODING

Characteristic of steep topography and small watersheds, flooding usually occurs within an hour, leaving little time for dry flood proofing measures such as the placement of closures around windows and doors or moving a facilities contents to igher ground.

ICE & DEBRIS FLOW

Flooding that involves impact forces will need to be addressed in the design of a solution.

SOIL TYPE

Permeable soils allow water to penetrate. A structure built on permeable soil, especially those with basements, may not be fit for waterproofing or sealants. This could result in the structure being damaged structurally by buoyancy forces.

BUILDING FOUNDATION

Whether the foundation is a slab-on-grade, crawl space, or walls will determine some of the options available. Also, structural stability will determine the extent of costs.

BUILDING CONSTRUCTION

Buildings of wood and aluminum construction may not be suitable for dry flood proofing measures while concrete and block constructed structures may be.

BUILDING CONDITION

If the building is not structurally sound, then measures such as raising or relocation may not be feasible.

The preceding considerations have been organized into the Flood Proofing Matrix shown in Figure 1. To use the matrix, homeowners should select the appropriate row for each of the characteristics shown that best reflects their situation. Where "N/A" shows in the row chosen, any corresponding flood proofing measure should be eliminated from further consideration, unless otherwise noted in the footnotes. Once a list of possible methods is determined, it should be checked against the pertinent community's building codes and floodplain management regulations. Those that meet community requirements should then be evaluated for other criteria such as economics, aesthetics, and risk. Economic benefits from flood proofing are discussed in Chapter 6. This should then lead to a choice of alternatives to be pursued further.

Another criteria to examine is the need to check state and local regulations with respect to other work which may need to be accomplished. For example, a substantially improved structure is required to be brought into compliance with the NFIP and Building Code standards for construction in the floodplain.

Figure 1

FLOOD PROOFING MATRIX

		FLOOD PROOFING MEASURES								
		Elevation on Foundation Walls	Elevation on Piers	Elevation on Posts or Columns	Elevation on Piles	Relocation	Floodwalls and Levees	Floodwalls and Levees with Closures	Dry Flood Proofing	Wet Flood Proofing
FLOODING CHARACTERISTICS	**Flood Depth**									
	Shallow (less than 3 feet)									
	Moderate (3 to 6 feet)								N/A	
	Deep (greater than 6 feet)						N/A	N/A	N/A	N/A
	Flood Velocity									
	Slow (less than 3 fps)									
	Moderate (3 to 5 fps)								N/A	N/A
	Fast (greater than 5 fps)	N/A[1]	N/A[1]				N/A[1]	N/A[1]	N/A	N/A
	Flash Flooding									
	Yes (less than 1 hour)	N/A[1]						N/A[2]	N/A[2]	N/A[2]
	No									
	Ice and Debris Flow									
	Yes	N/A						N/A	N/A	N/A
	No									
SITE CHARAC-TERISTICS	**Site Location**									
	Coastal Floodplain	N/A					N/A	N/A	N/A	N/A
	Riverine Floodplain									
	Soil Type									
	Permeable						N/A[3]	N/A[3]	N/A	
	Impermeable									
BUILDING CHARACTERISTICS	**Building Foundation**									
	Slab on Grade									
	Crawl Space									
	Basement		N/A	N/A	N/A				N/A	N/A[4]
	Building Construction									
	Concrete or Masonry				N/A[5]					
	Wood and Others				N/A[5]				N/A	N/A[4]
	Building Condition									
	Excellent to Good									
	Fair to Poor	N/A	N/A	N/A	N/A	N/A			N/A	N/A

Based on FEMA's Flood Proofing/Retrofitting Decision Matrix

Instructions for

Figure 1 —Flood Proofing Matrix

Step 1 – Select the appropriate row for each of the nine characteristics that best reflect the flooding, site, and building characteristics.

Step 2 – Circle the N/A (not applicable) boxes in the rows of characteristics selected.

Step 3 – Examine each column representing the different flood proofing measures. If one or more N/A boxes are circled in a column representing a flood proofing measure, that alternative should be eliminated from consideration unless special features (as footnoted) are applied to overcome the N/A concern.

Step 4 – Test the flood proofing measures that do not have circled N/A boxes for compliance with your community's flood plain management ordinance and building permit requirements.

Step 5 – Flood proofing measures that would be in compliance with community requirements should now be further evaluated for economic, aesthetic, risk, and other considerations. A preferred measure should evolve from this evaluation.

Step 6 – Obtain professional engineering and construction services for detailed design and implementation of the preferred flood proofing measure. Professional advice may rule out the preferred measure and an alternate measure will need to be selected.

N/A[1] : Fast flood velocity is conducive to erosion and special features include protective material to resist anticipated erosion.

N/A[2] : Flash flooding does not allow time for human intervention; thus, these measures must perform without human activity involved. Openings in foundation walls must be large enough to equalize water forces and should not have removable covers. Closures and shields must be permanently in place, and wet flood proofing cannot include last-minute modifications.

N/A[3] : Permeable soils allow seepage under floodwalls and levees; therefore, some type of cutoff feature would be needed beneath structures.

N/A[4] : Only selective features would be included that could waterproof individual items, relocate them above potential water levels, or avoid structural damage.

N/A[5] : The building must be temporarily relocated to place piles and complete foundation. If space is available this may be accomplished; however, additional expense will be involved.

CHAPTER 4: EXAMPLES OF FLOOD PROOFING PROJECTS

The following section outlines various flood proofing examples in Massachusetts, New England, and throughout the nation. Chapter 5 is an evaluation of the flood proofing costs which are presented here for each example. All costs have been updated to March, 1997 price levels for the Boston, Massachusetts area.

FLOOD PROOFING PROJECTS IN MASSACHUSETTS

Chatham, Massachusetts

Project Description

Following severe coastal flooding in 1991 and 1992, the Town of Chatham received a Hazard Mitigation grant from the Federal Emergency Management Agency (FEMA) to implement nonstructural flood protection measures at nine locations within the community. The project consisted of raising five residential dwellings approximately 1.5 feet above the base flood elevation and incorporating flood protection measures to four other homes. The flood protection measures included; waterproofing basements, installing floor drains, and elevating utilities above the base flood elevation.

Project Costs

The cost of performing the flood protection measures ranged from $17 to $36 per square foot for elevating a house and $2 to $3 per square foot for elevating utilities and flood proofing a basement.

Quincy, Massachusetts

Project Description

In 1994 the City of Quincy initiated a nonstructural flood damage reduction effort known as the "Flood-Prone Housing Retrofitting Program" to address repetitive loss properties along the coast. The following activities were accomplished under the Retrofitting Program:

- Dry flood proofing measures such as the sealing of windows, doors and bulkheads in existing basements; replacing windows above flood levels. Also, construction of exterior door and window wells. (4 houses)

- Wet flood proofing methods such as the construction of interior flood walls to protect furnaces and other heating/electrical systems and the construction of new utility rooms attached to the existing house. Elevation and/or relocation of the heating system, electric panel and, where possible, wiring and junction boxes, and other items such as washers, driers, and hot water heaters above the base flood elevation. (approximately 20 houses)

- Anchoring of structural members which are below the base flood elevation and anchoring and/or elevation of oil storage tanks.

- Construction of minor exterior floodwalls (e.g., construction of 18" high concrete flood wall around the bulkhead) and major exterior floodwalls, or levees. (3 houses)

- Elevating residential structures above the base flood elevation through fill, elevated foundations, shear walls, post, piles, and pier foundation and all related retrofitting of insulation, plumbing, wiring, utilities and site works. (4 houses)

Project Costs

Various flood proofing measures were undertaken as part of the retrofitting program. Wet flood proofing techniques were utilized for this project. Utility relocation and/or raising was accomplished at an average cost of $12,200 per household. This work frequently included the elevation of boilers and heating systems, hot water tanks, and electrical service boxes. The construction of utility rooms averaged about $12,900 per household.

Scituate and Falmouth FEMA Acquisition Activities

Project Description

Subsequent to coastal flooding resulting from Hurricane Bob in August 1991, the Halloween Storm of 1991, and the December 1992 storm, properties in Scituate and Falmouth were purchased under Section 1362 of the National Flood Insurance Program (the 1362 program is no longer available). This flood proofing activity removed houses which were continually being damaged by coastal storm events, thereby reducing overall damages.

Project Costs

A total of fifteen houses were purchased under this program at an average cost of about $131,400 per property. Obviously, the cost of acquiring property is highly variable depending on the location and size of the parcel, and the number and type of structures to be purchased, if any. For example, acquisition costs for a Corps project located along the Pawtuxet River (Belmont Park) in Rhode Island were about $91,400 per property. The difference in costs of acquisition between the Scituate/Falmouth project and the Pawtuxet project is due in part to location. The Scituate/Falmouth project was located along the coast while the Pawtuxet project is adjacent to an inland river. At Point Beach, Milford, Connecticut (a coastal neighborhood on Long Island Sound), a COE study estimated the average acquisition cost per property at $142,000.

CORPS OF ENGINEERS FLOOD PROOFING PROJECTS IN NEW ENGLAND

Point Beach, Milford, Connecticut

Project Description

Milford is a coastal community located in the south-central part of Connecticut on Long Island Sound. Point Beach is a residential neighborhood situated directly on Long Island Sound consisting of one- and two-story houses which are primarily year-round residences. The most recent tidal flooding experienced at Point Beach occurred during October 1991 and December 1992 storms which resulted in extensive property loss and damages. Heating systems and other utilities were damaged by high water and, in many cases, the flooding exceeded the first floor elevation.

The New England District has completed plans and specifications for undertaking a hurricane and storm damage reduction project consisting of elevating 55 houses of timber construction above the base flood elevation. The project consists of raising the structures an average of 4 to 5 feet above their present elevation. Twenty-three of the houses are 1-story structures and the remainder are 2-story structures. Most houses have concrete masonry unit (CMU) foundation walls in conjunction with CMU interior columns. A few of the houses are supported solely on CMU columns.

The houses to be raised are in two separate FEMA designated flood zones. Twelve of the 64 houses are located in the V-Zone and are therefore subjected to wave impacts. The remainder are in the FEMA designated A-Zone. In general, the houses located in the A-Zone will be raised by extending the foundation walls and columns with new reinforced CMU. The houses in the V-Zone will typically require their existing foundations to be completely removed and replaced with reinforced concrete columns on spread footings.

Project Costs

The following analysis of project costs is based on estimated costs since the project has not yet been implemented. The average cost to raise the Point Beach structures are sub-divided into those structures located in the A-Zone and those in the V-Zone. For structures in the A-Zone, 1-story houses averaged $49 per square foot versus $65 per square foot for 2-story houses. All houses in the V-Zone (subjected to wave impacts) are 2-story and averaged $69 per square foot. These differences in average costs can be attributed to the overall size of the structures (one versus two stories) and the type of construction necessary for the different flood zones. For example, houses in the V-Zone must be anchored to the new foundation and must also be designed to withstand wave impacts.

Belmont Park, Warwick, Rhode Island

Project Description

A June 1982 investigation of flooding problems on the Pawtuxet River in Warwick, Rhode Island identified a 38-acre residential area of Warwick, known as Belmont Park, as prone to frequent and severe flooding. The recommended plan, authorized by the Corps and implemented from September 1982 to July 1985, was the purchase or relocation of 61 houses; the purchase of 19 privately owned vacant lots; and the construction of 12 above ground utility room additions to residences that experienced less severe flooding. The Corps also participated with the National Weather Service in the development of a flood warning system to further protect those houses which could be evacuated and where the structures' contents could be protected.

Project Costs

The cost of the entire project was approximately $4 million. The project costs associated with the Belmont Park project can be divided into three groups: 1) building demolition and site work; 2) implementation of a flood warning system; and, 3) construction of utility rooms.

1) Structures to be demolished included houses, garages, and sheds. Building demolition and site work also included the removal of septic tanks, utilities, driveways, walkways, and debris and loaming and seeding the disturbed areas. The cost for this work was about $10,200 per structure removed.

2) The flood warning system installed for this site encompassed the entire Pawtuxet River Basin with a drainage area of 230 square miles. It included three stream gages and four precipitation gages, hardware and other field equipment. The entire system was about $88,300.

3) The construction of an 8 feet x 12 feet utility room has been estimated at $17,700 or about $184 per square foot.

NATIONALLY RECOGNIZED FLOOD PROOFING PROJECTS

The Corps National Flood Proofing Committee has documented numerous projects throughout the United States which have utilized nonstructural techniques to reduce or eliminate flood damages. While the construction costs for these projects vary significantly based on geographic region, the projects themselves serve as examples of applications of the discussed techniques to solve flooding problems. The costs provided below have been adjusted to 1997 price levels for Boston, Massachusetts.

Tampa, Florida

Project Description

This project consisted of raising or relocating slab-on-grade structures with the slab still attached. This work was accomplished in the Tampa-St. Petersburg area of the Florida Gulf coast. Their foundations consisted of a reinforced concrete perimeter grade beam, in some cases supporting a concrete block foundation wall, filled with compacted soil with a floor slab poured on top. The exterior wall construction was concrete block.

This project dealt specifically with raising houses with the slab attached. The lifting and/or moving procedures are essentially the same whether the slab is attached or not. The principal differences lie in the preparation of the structure for lifting and/or moving, and the design of and reattachment to, the new foundation. The houses were raised using lifting beams placed beneath the floor slab. Concrete block pier-type foundations with spread footings were constructed at the new sites.

Project Costs

The cost estimates provided below are for elevating a residential structure in place two to ten feet above the present grade level. The estimates assume the structure is an approximately 1,300 square foot, single story house with a detached garage. The existing foundation is assumed to be typical slab-on-grade with a perimeter grade beam and interior beams beneath bearing walls. The new foundations consist of reinforced concrete piers.

The cost of elevating this type of structure 2 feet is approximately $36 per square foot. The cost for elevating it 10 feet would be approximately $45 per square foot. These estimates do not include landscaping costs which can be about $7 per square foot of yard space.

Dry Creek, Goodlettsville, Tennessee

Project Description

The Dry Creek Project is located near Nashville, Tennessee and was constructed to reduce flood damages within a residential subdivision. The project consisted of raising these nineteen houses above the 100-year flood elevation.

All of the houses were one-story, brick veneer, in sound structural condition. The houses were 1,000 to 1,475 square feet in size, and the elevated heights ranged from 2 to 6 feet. The general work involved with raising these houses included: 1) site work such as removing shrubbery and fences for equipment access to the foundation, 2) preparing the foundation walls for placement of the lifting beams, 3) disconnecting the utilities, 4) elevating the structure using hydraulic jacks, 5) constructing new footings and masonry block foundations, and 6) landscaping.

Project Costs

Elevating-in-place construction costs for the nineteen houses ranged from \$39,300 to \$53,700 at 1997 price levels. The major variables which influenced the costs were the number of entrances/exits, the height of the raise, size of foundation perimeter, and the existence of porches and garages. The average cost per square foot of house is about \$38 adjusted for Boston, Massachusetts, 1997 price levels.

CHAPTER 5: EVALUATION OF FLOOD PROOFING COSTS

The following evaluation of flood proofing costs compares general cost guidelines found in various flood proofing literature to actual flood proofing project costs, such as those presented in the previous chapter. For comparison purposes, all costs have been updated to 1997 price levels for Boston, Massachusetts.

NATIONAL FLOOD PROOFING COMMITTEE COST ESTIMATING GUIDELINES

The cost of flood proofing a building depends on a variety of factors including the building's condition, the flood proofing technique to be employed, and other site-specific issues such as soil conditions and flooding levels. Flood proofing construction costs adjusted for location and updated to March 1997 price levels are provided in Table 2 to assist in economic analysis and to provide estimates of costs for reconnaissance type planning of flood proofing measures. This data (except for Wet Flood Proofing) was derived from actual construction costs obtained from FEMA, the Corps of Engineers, and other sources. It was then adjusted to March 1997 price levels for Boston using *Means Construction Costs* publications and the *Engineering News Record*. This cost data also includes the contractor's profit. The Wet Flood Proofing data was obtained from a 1986 FEMA design manual for retrofitting flood-prone structures and has also been adjusted to March 1997 price levels for Boston.

This section is a comparison evaluation of the various flood proofing costs presented in this report. The actual costs of flood proofing presented in Chapter 4 are compared with national average costs presented in Table 2. Other example costs are provided for comparison purposes as well. As previously noted, all costs are provided in 1997 dollars adjusted for the metropolitan Boston area.

TABLE 2

Example Flood Proofing Costs

Elevation

Wood Frame Building on Piles, Posts or Piers[1]	$36 per square foot
Wood Frame Building on Foundation Walls[1]	$35 per square foot
Brick Building[1]	$58 per square foot
Slab-on-Grade Building[1,2]	$54 per square foot

[1]*These costs include foundation, extending utilities, and miscellaneous items, such as sidewalks and driveways. They do not include the cost of fill or landscaping.*

[2]*The unit cost is based on a 2-foot raise. Add $1 per square foot for each additional foot raise up to eight feet.*

Fill (includes hauling and compaction)	$14 per cubic yard
Landscaping (no trees, bushes, or flowers)	$ 7 per square foot

Relocation

Moving Building (complex buildings being moved several miles)	$14 per square foot
Moving Building (simple wood frame building being moved a few hundred feet)	$ 7 per square foot

Additional costs for this measure will include: the appropriate elevation cost listed above and may also include: fill, lot, landscaping, and pertinent indirect costs.

Floodwalls and Levees

Floodwalls, two feet above ground level	$138 per linear foot
Floodwalls, four feet above ground level	$202 per linear foot
Floodwalls, six feet above ground level	$285 per linear foot
Levees, two feet above ground level	$ 47 per linear foot
Levees, four feet above ground level	$ 86 per linear foot
Levees, six feet above ground level	$144 per linear foot

Levee costs include landscaping. Additional costs that may need to be estimated for both floodwalls and levees are as follows:

TABLE 2 (cont.)
Example Flood Proofing Costs

Floodwalls and Levees (cont.)

Interior Drainage	$5,100 lump sum
Closures	$.91 per square foot
Riprap	$.39 per cubic foot
Sidewalk	$13 per linear foot
Driveway (Asphalt)	$ 8 per square yard
Driveway (Concrete)	$23 per square yard

Dry Flood Proofing

Sprayed-on cement (1/8 inch)	$ 4 per square foot
Asphalt (2 coats below grade)	$ 1 per square foot
Periphery drainage	$39 per linear foot
Plumbing check valve (6")	$830 lump sum
Pump (submersible sump)	$712 lump sum
Flood shields	
Metal	$99 per square foot
Wood	$35 per square foot

Wet Flood Proofing[2]

Shielding enclosure (6 feet x 8 feet, with sump pump)	$377 lump sum
Utility relocation to existing space	$3,022 lump sum
Construct utility room	$42 per square foot

2 Design Manual for Retrofitting Flood-prone Residential Structures; FEMA (1986)

ELEVATING & RELOCATING STRUCTURES

The cost of elevating a structure is dependent on numerous factors including, but not limited to, type of structure (wood frame, brick) and foundation (slabs, piles), size and shape of structure (number of exits and stories), site conditions (access), the height to which the structure is to be raised, and the lifting or raising procedures used. All of these factors combine to influence the cost of elevating the structure.

The national average listed in Table 2 is $35 per square foot for a wood frame structure elevated on foundation walls. It appears that this is consistent with flood proofing projects in Chatham and Quincy. However, it is considerably lower than that for Point Beach which encountered unforeseen problems with the poor condition of existing foundations and footings, thereby increasing overall costs of the Point Beach project. The foundation and footings of some houses were found to be inadequate for extending to a higher elevation and had to be rebuilt increasing the overall cost of the project. Other information[3] pertaining to the midwest and the south suggests that elevation of residential structures costs about $37 per square foot for a slab-on-grade house raised 2 feet to $42 per square foot for a brick veneer structure raised less than 3 feet. Although these costs have been adjusted for the New England region, they are still considerably lower than the national average costs (Table 2) per square foot of $55 per square foot for a slab-on-grade house and $58 per square foot for a brick house.

The use of the national average cost per square foot for raising residential structures should be used with caution. It is recommended that the national averages presented in table 4 be used to represent only the lower range of house raising costs in the New England region. Therefore, the national average costs in Table 2 should be used as a "lower end" value only.

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[3] Design Manual for Retrofitting Flood-prone Residential Structures; FEMA (1986)

Another method of estimating house raising costs has been developed using actual flood proofing cost data from the Dry Creek, Goodlettsville, Tennessee flood proofing project completed by the Corps of Engineers Nashville District. The data was used to derive the following equation:

House Raising Cost = \$11,360 + \$12.60/Sq.Ft. x (Square footage) + \$970/Ft. x (Ht. Raised in ft.)

The use of the Dry Creek equation as a cost estimating tool provides a conservative estimate for planning level purposes. However, this equation should only be used for similar situations as occurred at Dry Creek, most notably, 1-story houses of wood frame construction with crawl spaces.

The Dry Creek equation did not yield results consistent with the actual estimated costs for the Point Beach project. The Dry Creek equation results were about \$16 per square foot less than the actual estimated costs for 2-story homes in Point Beach. This reinforces the need to use this cost estimating tool for only appropriate situations. The physical house characteristics at Point Beach do not match the parameters required for using the Dry Creek equation.

When the Dry Creek cost estimating equation is applied to the Chatham house raising project, the average estimated costs are about \$10 per square foot more than the actual costs incurred for raising the Chatham houses. The actual average cost for this project was about \$29 per square foot versus \$39 per square foot calculated using the Dry Creek equation. This is likely due in part to simpler construction of the houses (wood frame cottages) raised in Chatham versus those used to develop the Dry Creek cost estimating equation (wood frame with brick veneer).

The Dry Creek equation was also applied to the Quincy house raising project. This yielded an average estimated cost about \$6 per square foot more than the actual costs incurred during the project. The actual average cost for this project was about \$28 per square foot versus $35 per square foot calculated using the Dry Creek equation.

These examples reinforce the need to use a cost estimating tool such as the Dry Creek equation only for appropriate situations; in this case, 1-story houses in sound structural condition with crawl spaces. Therefore, it appears that the use of the Dry Creek equation as a cost estimating tool would provide a conservative estimate for planning level purposes.

Relocating houses out of the floodplain is also a consideration for flood proofing. Although relocation is a retrofitting technique that can offer the greatest security from future flooding, it may also be one of the most expensive. Relocation of residential houses costs approximately $7 to $14 per square foot based on the national average and depending on the distance the building is being moved. It appears that the costs presented for the national averages are adequate for obtaining planning level estimates of residential house relocation in Massachusetts. This relocation cost is strictly the cost of moving the structure and does not include the cost of the new lot, foundation, or other site work.

LEVEES & FLOODWALLS

The cost of constructing floodwalls or levees as a flood proofing alternative can be prohibitive to a single homeowner. The national average cost for floodwalls ranges between approximately $130 to $290 per linear foot of floodwall. Levees are significantly less expensive than floodwalls, but require a significant amount of space due to their sloping sides. The average cost of levee construction ranges between approximately $45 and $140 per linear foot.

It appears that the use of the national average costs for levee construction are an adequate tool for developing planning level cost estimates. Hence, for planning level estimates, the national averages for floodwall construction may provide a conservative estimate.

DRY FLOOD PROOFING

This flood proofing technique includes the use of closures and sealants. Closures are usually wood (plywood) or metal (aluminum). Sealants include heavy gauge polyethylene membranes, asphalt coatings, and sprayed on cement. Retrofitting a brick faced wall by adding an additional layer of brick with a seal placed in between is also an effective sealant. No specific cost examples for either closures or sealants were obtained and the information in Table 2 should be used.

WET FLOOD PROOFING

Wet flood proofing includes the use of shielding for low level flooding, anchoring of storage tanks, utility relocation/elevation, and plumbing system protection. Shielding can be accomplished by placing a small floodwall around the affected area.

Wet flood proofing techniques such as the protection of utilities were used extensively in the Quincy flood proofing project. Utility relocation and raising averaged about $12,200 per house for the Quincy project. Other nationwide sources of information indicate that utility relocation to an existing space averages almost $3,300, well below the costs shown in the Quincy project. The construction of two utility rooms averaged about $12,900 each for the Quincy project, although their size is unknown.

CHAPTER 6: FLOOD PROOFING ECONOMIC BENEFITS

This chapter describes the economic benefits of flood proofing. The potential for flood damage is determined by the depth of flooding and the number of times a building and its contents may be flooded. Flood proofing will save a homeowner money that would otherwise be spent to repair and clean up the building and its contents after a flood. Also, damages prevented by flood proofing will reduce the inconvenience and annoyance caused by the time consuming process of cleaning up and repairing a building. Other benefits of flood proofing may include less time off from work, improved health and safety, and other intangible benefits.

There are also flood proofing benefits which may not be readily apparent to homeowners, particularly those who have never experienced flooding. These secondary benefits may include avoiding the expense and inconvenience of staying elsewhere after suffering flood damages, and reducing the hours spent away from their jobs while cleaning and repairing flood damaged buildings. A flooded business could result in loss of wages, reduced profits, or delays in receiving goods and services.

The benefit from flood proofing is the prevention of damages that otherwise would have occurred without flood proofing. Flood proofing benefits can be quantified through an economic analysis conducted for either a specific house or an entire neighborhood. Before a town or homeowner can begin implementing a flood proofing project, they must conduct an economic analysis of the alternatives selected. One method to quantify flood proofing benefits is described in "Flood Proofing - How To Evaluate Your Options" published by the National Flood Proofing Committee, July 1993.

CHAPTER 7: SUMMARY

Flood proofing is defined as "any combination of structural or non-structural changes or adjustments incorporated in the design, construction, or alteration of individual buildings or properties that will reduce flood damages." Flood proofing includes any efforts property owners may take to reduce flood damages to buildings or their contents.

Typically, there are two types of solutions that can be formulated to reduce flood damages; structural and nonstructural. Structural solutions are those measures that include wet and dry dams, channels, dikes, walls, and diversion channels. The intent of these solutions is to reduce the frequency and/or the amount of damaging flows. Nonstructural solutions can include permanent relocation of structures, flood warning systems, and the regulation of floodplain lands. The intent of nonstructural solutions is to reduce flood losses without changing the nature or extent of the flooding. This can be accomplished through either reducing the number of times the building is flooded or limiting the potential damage to a building and/or its contents when it is flooded. Non-structural flood proofing measures include elevating buildings, relocating or protecting damageable property within a building, sealing walls, protecting utilities, and temporary closures. Floodwalls and levees around individual buildings and relocation or raising of structures are also flood proofing measures.

This document has provided a brief description of various flood proofing measures and their respective average costs. Listed below are the flood proofing measures and the cost findings of this study.

Elevating and Relocating Structures

It is recommended that the national averages be used to represent only the lower range of house raising costs in the New England region. Therefore, the national average costs presented in Table 2 should be used as a "lower end" value only. Also, the Dry Creek equation is an appropriate cost estimating tool when used for structurally sound 1-story houses of wood frame construction with crawl spaces.

The national averages for residential house relocation for Massachusetts are adequate for obtaining planning level estimates. However, this relocation cost is strictly the cost of moving the structure and does not include the cost of the new lot, foundation, or other site work.

Floodwalls and Levees

It appears that the use of the national average costs for levee construction are an adequate tool for developing planning level cost estimates. Also, the national averages for floodwall construction may provide a conservative estimate for planning level estimates.

Dry Flood Proofing & Wet Flood Proofing

Since no specific cost examples were available for the dry flood proofing measures of closures or sealants, the costs listed in Table 2 should be used.

In Massachusetts, wet flood proofing such as utility relocation and elevating averages about $11,900 per house. The construction of a utility room averaged about $12,600.

APPENDIX A

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APPENDIX A

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APPENDIX B

GLOSSARY

Stillwater Elevations - The elevation that the surface of water would assume if all wave action were absent.

Uplift - The hydrostatic pressure caused by water under a building.

V-Zone - Flood area subject to wave action.

Wet Flood Proofing - This involves allowing the structure to be flooded but ensuring, either through permanently or temporarily relocating contents and utilities, that damage is minimized.